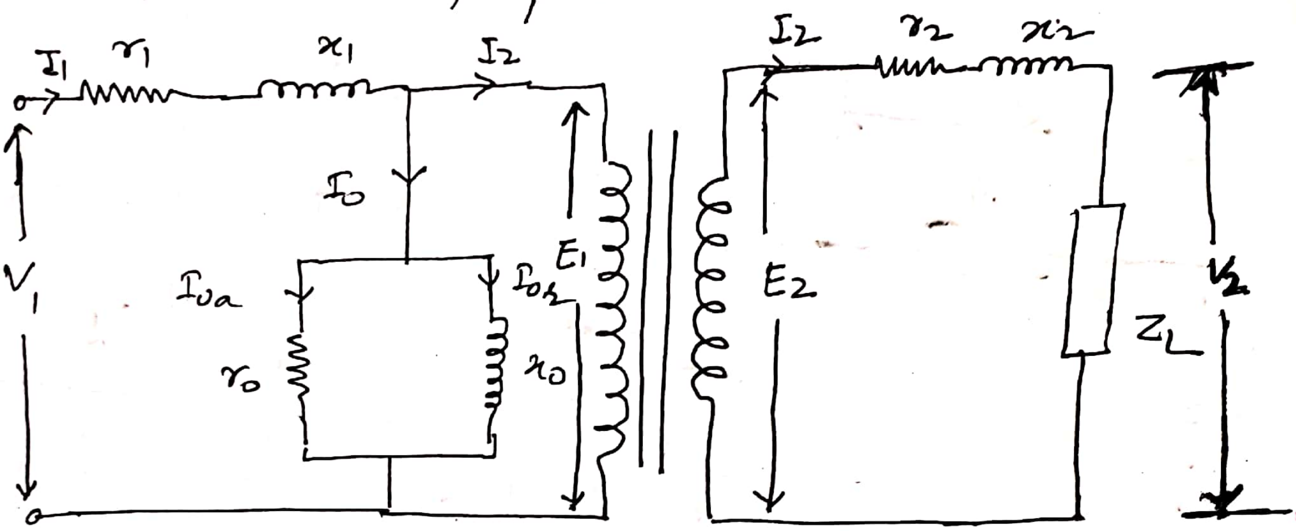
(Exact Equivalent ckt of T/f^2)



$$\bar{I}_1 = \bar{I}_0 + \bar{I}_2'$$

$$\bar{I}_0 = \bar{I}_{oa} + \bar{I}_{or}$$

I_{oa} = Active Component of I_0 = $I_0 \cos\phi_0$

I_{or} = Reactive Component of I_0 = $I_0 \sin\phi_0$

$r_0 = \frac{V_1}{\quad}$

Equivalent ckt of a Transformer :

Primary side | Secondary side

Primary side :

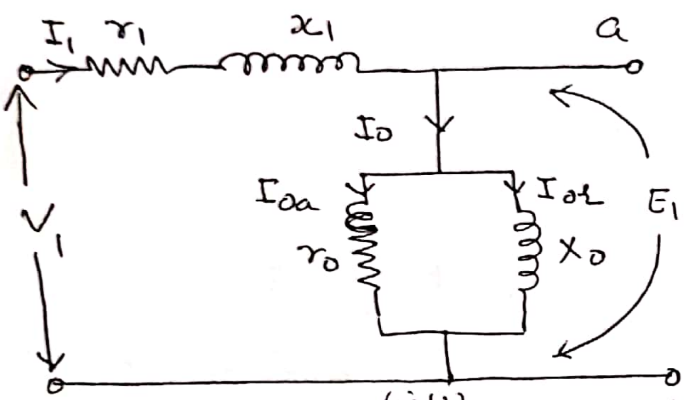


fig (1)

r_1 = resistance of primary winding

x_1 = leakage reactance of primary winding

$$\boxed{P_i = V_1 I_0 \cos\phi_0}$$

$I_0 < \begin{matrix} I_{0a} \\ I_{0r} \end{matrix}$

$$I_0 = \sqrt{I_{0a}^2 + I_{0r}^2}$$

I_{0a} = Active Component of no load current

$= I_0 \cos\phi_0$

$\cos\phi_0$ = no load power factor

I_{0r} = Reactive Component of no load current (magnetising current)

$= I_0 \sin\phi_0$

P_i (iron loss) $= I_{0a}^2 r_0$

r_0 = fictitious resistance, consider to take into account iron losses of transformer

x_0 = magnetising reactance.

$$V_1 = I_1 (r_1 + jx_1) + E_1 \quad \text{——— (1)}$$

$r_0 = \dfrac{V_1}{I_{0a}}$

$x_0 = \dfrac{V_1}{I_{0r}}$

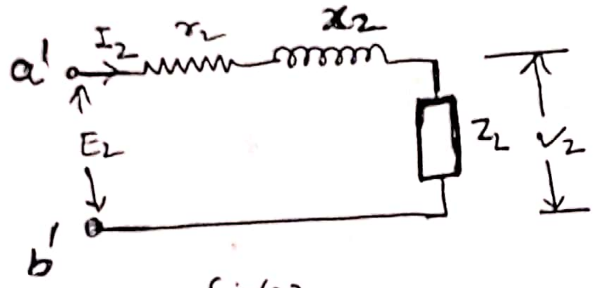
Note:→

* I_{0a} & I_{0r} are voltage dependent, therefore parameters r_0 & x_0 are connected in parallel.

r_1 & x_1 are current dependent, therefore these parameters are connected in series

* The parameters of magnetising branch I_0, I_{0a}, I_{0r}, r_0, x_0 are dependent upon primary voltage applied V_1. These parameters are independent of the load current of T/F. Therefore the magnetising branch is shown in ||el to applied voltage V_1.

Secondary Side:



Z_L = low impedance

fig(2)

$$E_2 = V_2 + I_2(r_2 + jx_2) \quad — ②$$

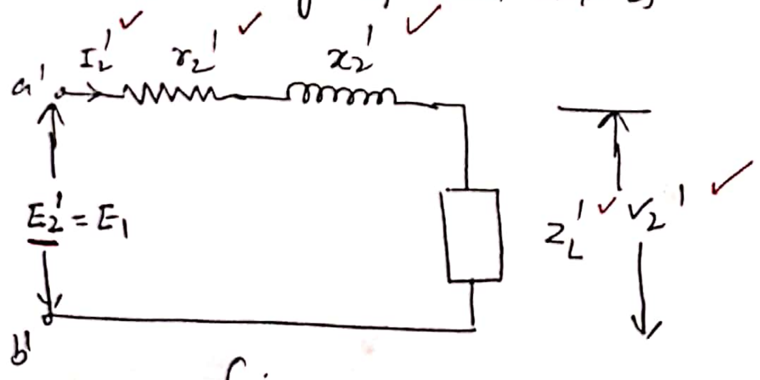
$$V_2 = I_2 Z_L$$

Joining of primary & secondary equivalent ckts:

In order to find a single equivalent ckt of transformer, equivalent ckts of fig(1) & (2) should be joined together. They can only be done when voltage b/w a, b & a', b' are equal.

In order to join the two equivalent ckts, the actual secondary wdg is replaced by an $\boxed{\text{equivalent secondary wdg}}$ such that the values E_2', I_2', r_2', x_2', V_2' and Z_L' are called referred values to primary side

The new secondary equivalent ckt is

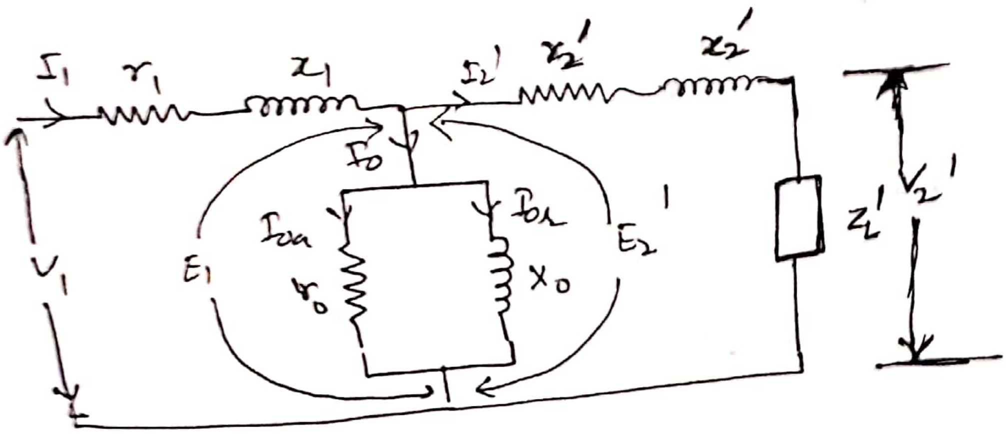


fig(3)

$$E_2' = V_2' + I_2'(r_2' + jx_2')$$

$$V_2' = I_2' Z_L'$$

The voltage b/w a & b of fig (1) & a' b' of fig (2) are equal &
Therefore equivalent ckts can be joined together.



Exact equivalent ckt of transformer.

① Referring secondary values to primary side:

VA → Same $E_2' I_2' = E_2 I_2$ ① (Volt-ampere should be same)
VA

$$\frac{I_2'}{I_2} = \frac{E_2}{E_2'}$$

$$\frac{E_1}{E_2} = \frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1} = k$$

$$\boxed{I_2' = \frac{E_2}{E_1} I_2}$$

$E_2' = E_1$

$$\boxed{I_2' = \frac{1}{k} I_2}$$

② Load-volt ampere should be same,

Load VA → Same $V_2' I_2' = V_2 I_2$ ⇒ $V_2' = \frac{I_2}{I_2'} V_2$

$$V_2' = \frac{V_2}{I_2'} I_2$$

$$\boxed{V_2' = \frac{I_2}{I_1} V_2}$$

$$\frac{I_2}{I_1} = a = k$$

$$\frac{I_2}{I_2'} = a$$

$I_1 \sim I_1'$

$$\frac{I_1'}{I_1} = k$$

$$= \frac{V_2}{\cancel{I_2}} \cancel{I_2} k$$

$$\boxed{V_2' = k V_2}$$

③ Copper loss should be same.

(P_{cu}) → Same sec $I_2'^2 r_2' = I_2^2 r_2$

$$r_2' = \left(\frac{I_2}{I_1}\right)^2 r_2$$

$$r_2' = \frac{I_2^2}{I_2'^2} r_2 = \frac{\cancel{I_2^2}}{\cancel{I_2^2}} k^2 r_2$$

$$r_2' = \left(\frac{I_2}{I_1}\right)^2 r_2$$

$$\boxed{r_2' = k^2 r_2}$$

④ Per unit leakage reactance drop should be same.

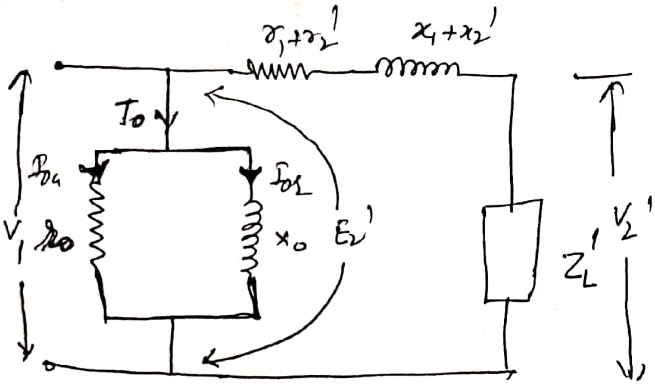
$$\frac{I_2' X_2'}{E_2'} = \frac{I_2 X_2}{E_2}$$

$$X_2' = \frac{I_2 X_2}{E_2} \cdot \frac{E_2'}{I_2'}$$

$$= \frac{\cancel{I_2} X_2}{E_2} \cdot \frac{E_2'}{\cancel{I_2}} \cdot k \qquad E_2' = E_1$$

$$\boxed{X_2' = k^2 X_2}$$

In order to simplify the calculations, approximate equivalent ckt :



$$R_{01} = r_1 + r_2' \qquad \Big| \; r_2' = k^2 r_2$$

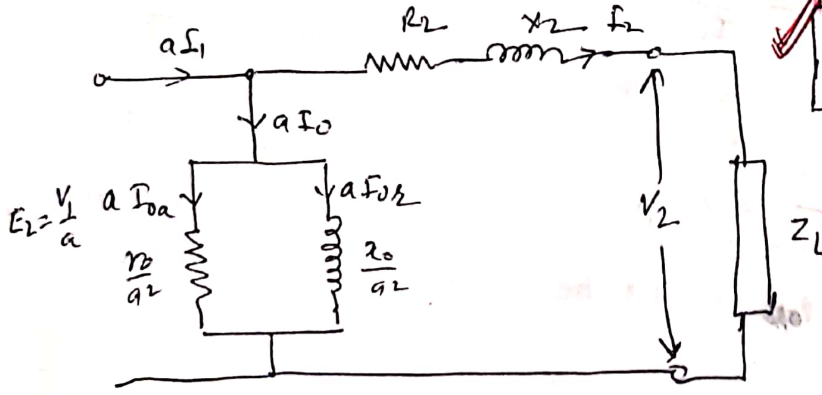
$$R_{01} = r_1 + k^2 r_2$$

$$X_{01} = x_1 + x_2'$$

$$= x_1 + k^2 x_2 \qquad \Big| \; x_2' = k^2 x_2$$

$$Z_{01} = \sqrt{R_{01}^2 + X_{01}^2}$$

Approximate equivalent ckt referred to the secondary side



$$\boxed{\frac{E_1}{E_2} = \frac{V_1}{V_2} = \frac{T_1}{T_2} = \frac{I_2}{I_1} = a}$$

or k

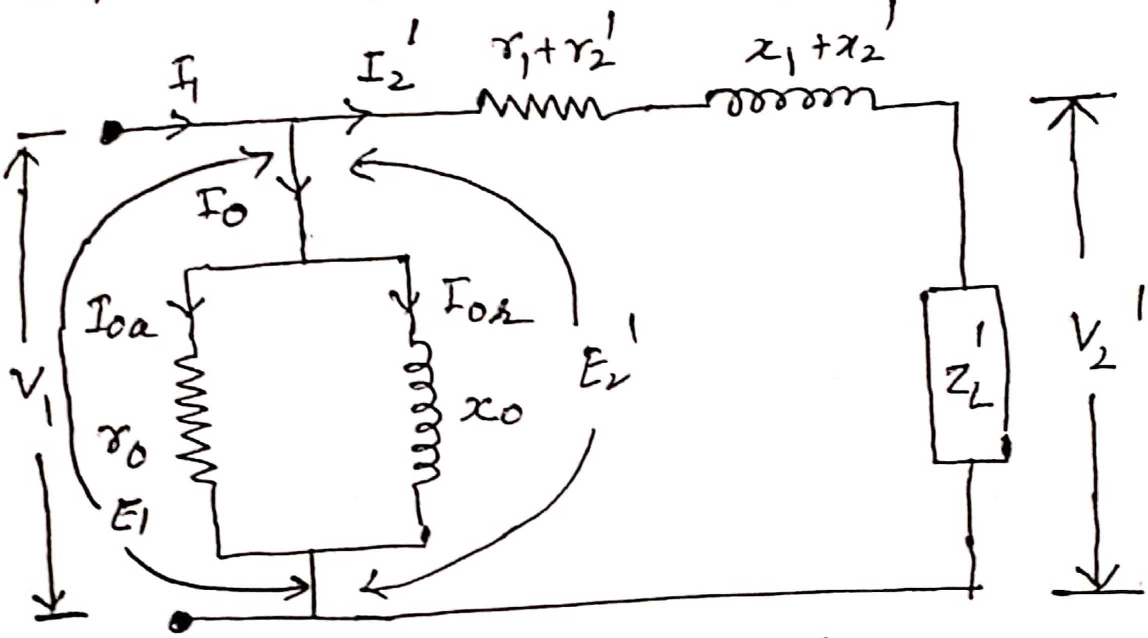
$$\boxed{\begin{aligned} R_{02} &= r_2 + \frac{r_1}{k^2} \\ X_{02} &= x_2 + \frac{x_1}{k^2} \\ Z_{02} &= \sqrt{R_{02}^2 + X_{02}^2} \end{aligned}}$$

$$R_2 = r_2 + \frac{r_1}{a^2} \qquad X_2 = x_2 + \frac{x_1}{a^2}$$

$$Z_2 = R_2 + jX_2$$

$$I_2 = \frac{V_2}{Z_L} = \frac{E_2}{Z_2 + Z_L} \qquad \frac{V_1}{a} = E_2 = V_2 + I_2 Z_2$$

* **Approximate equivalent ckt of transformers when all parameters referred to primary side.** $\frac{E_1}{E_2} = \frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1} = k$



$$R_{eq_1} = r_1 + r_2' \quad ; \quad r_2' = k^2 r_2$$

$$X_{eq_1} = x_1 + x_2' \quad ; \quad x_2' = k^2 x_2$$

$$Z_{eq_1} = \sqrt{R_{eq_1}^2 + X_{eq_1}^2}$$

$$I_2' = \frac{I_2}{k} \qquad I \propto \frac{1}{V \to k}$$

$$V_2' = k V_2 \text{ at } (\text{कत})$$

$$V_2' = I_2' Z_L'$$

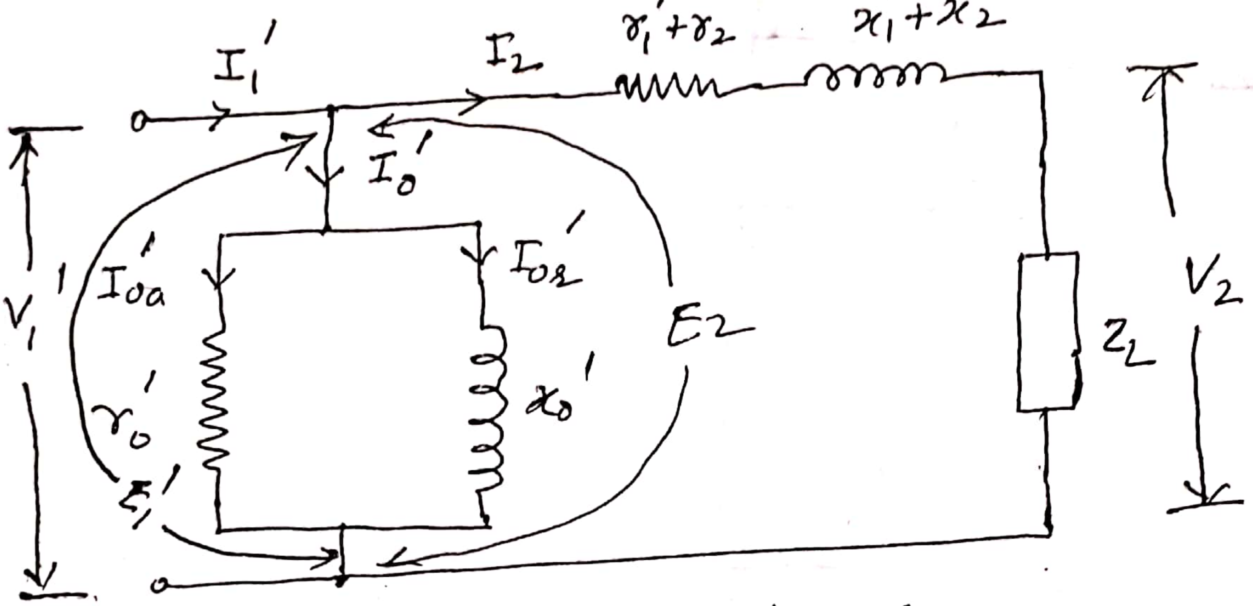
R_{eq_1} = Total resistance or Equivalent resistance as referred to primary side

X_{eq_1} = Total leakage reactance or Equivalent leakage reactance as referred to primary side

* In order to simplify calculations.

Approximate equivalent ckt of transformer when parameters as referred to secondary side

$$\frac{E_1}{E_2} = \frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1} = k$$



$$R_{eq_2} = r_2 + r_1' \quad ; \quad r_1' = \frac{r_1}{k^2}$$

$$X_{eq_2} = x_2 + x_1' \quad ; \quad x_1' = \frac{x_1}{k^2}$$

$$Z_{eq_2} = \sqrt{R_{eq_2}^2 + X_{eq_2}^2}$$

R_{eq_2} = Total resistance as referred to secondary side

X_{eq_2} = Total leakage reactance as referred to secondary side.

$I_1' = k I_1$	$I_{0a}' = k \cdot I_{0a}$	$r_0' = \dfrac{r_0}{k^2}$
$I_0' = k I_0$	$I_{0\mu}' = k\, I_{0\mu}$	$x_0' = \dfrac{x_0}{k^2}$
$V_1' = \dfrac{V_1}{k}$		